Disinfecting Unfiltered Secondary Effluent Meeting The Challenge With Low Pressure - High Intensity UV Systems

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ABSTRACT

The City of Manteca discharges secondary effluent to the San Joaquin River near Stockton in Northern California. Chlorination and dechlorination of secondary effluent has been accomplished historically with chlorine and sulfur dioxide gas utilizing a converted sedimentation basin as a chlorine contact tank. Because of poor hydraulics and a partially-nitrified effluent, satisfying NPDES coliform requirements consistently with conventional chlorination practices has proven difficult. As part of an expansion and upgrade of the 7 mgd plant, construction of a UV disinfection system was considered. To determine the feasibility of disinfecting unfiltered secondary effluent with UV light, a survey of treatment plants in the United States and the United Kingdom was undertaken in conjunction with an equipment supplier prequalification process. Pilot testing of a low pressure-high intensity UV disinfection system was subsequently initiated to confirm design dosages and operational parameters required to achieve a total coliform standard of 23 MPN/100 mL with low transmittance secondary effluent. The results of the pilot study, treatment plant survey, and preliminary design for the proposed 10 mgd disinfection facility are presented in this paper along with projected capital and operation and maintenance costs.

KEY WORDS

Unfiltered secondary effluent, low pressure-high intensity

BACKGROUND

Background information includes a description of the existing components at the Manteca Wastewater Quality Control Facility (WQCF), a discussion of the proposed Phase III Expansion Project, and a summary of current waste discharge requirements at the plant.

Description of Existing Plant

The Manteca WQCF is a combined biofilter-activated sludge plant. The regional facility serves the incorporated cities of Lathrop and Manteca, including one food processing industry. The facility is located approximately halfway between the two communities within 210-acres of City of Manteca owned property. The current design capacity of the Manteca WQCF is 6.95 mgd (average flow) and 13.45 mgd (peak flow).

The facility consists of an influent pump station, coarse mechanical screens, aerated grit tanks, primary sedimentation basins, biofilter feed pump station, roughing biofilters, fine-bubble activated sludge aeration basins, secondary clarifiers, and chlorine contact tank. Solids handling facilities include primary and secondary sludge pumps, dissolved air flotation thickeners, anaerobic digesters, and paved sludge drying beds. A schematic flow diagram is included as Figure 1.

Secondary effluent from the plant is land applied to City owned or leased properties during the spring and summer (flood irrigation for agricultural production) and discharged to the San Joaquin River primarily during the winter (October - March). Land application of wastewater is maximized, however, due to hydraulic constraints, some year-round discharge of secondary effluent to the river occurs. In terms of beneficial reuse of biosolids, dried sludge is spread on agricultural lands adjacent to the plant site as a soil amendment and crop fertilizer.

Discussion of Phase III Expansion Project

The Phase III expansion of the Manteca WQCF is anticipated to begin late in the Year 2000. Improvements proposed at the plant will increase the Phase II treatment capacity from 6.95 mgd to 9.87 mgd (average dry weather flow) with the peak wet weather flow capacity increasing from 13.45 mgd to 19.15 mgd. Facilities to be added include the following:

1. Influent pump station with mechanical screens
2. Two primary sedimentation basins
3. Two aeration basins equipped with fine-bubble diffused air systems
4. Two secondary clarifiers

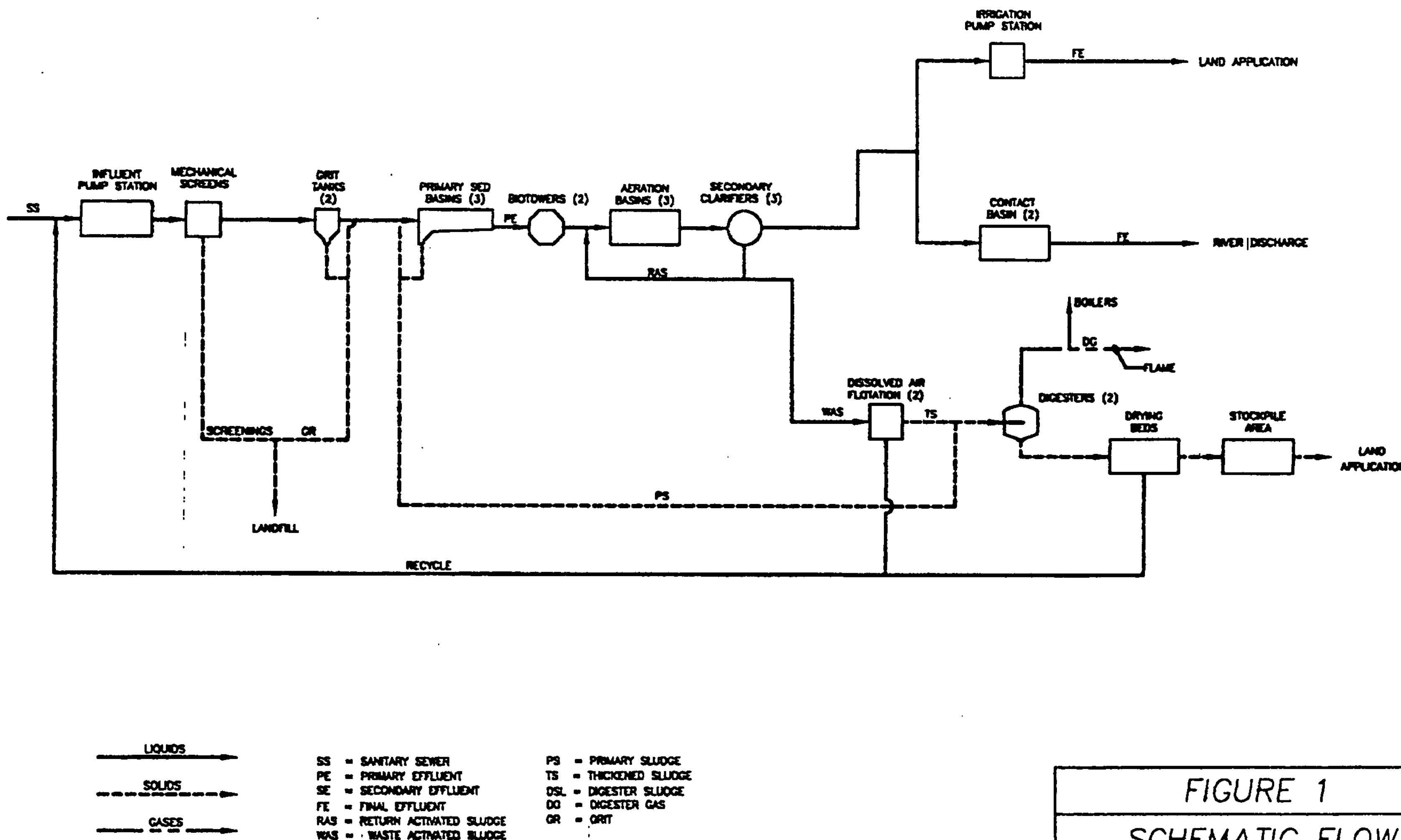

FIGURE 1

SCHEMATIC FLOW DIAGRAM OF EXISTING MANTECA WQCF TREATMENT TRAIN

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5. Secondary effluent disinfection system
6. Effluent pumping station
7. Anaerobic digester and cogeneration system
8. High-solids sludge centrifuges

Summary of Effluent Discharge Requirements

Effluent from the Manteca WQCF discharged to the San Joaquin River must be disinfected to meet coliform standards established by the Regional Water Quality Control Board. Current bacteriological limits for the plant effluent are as follows:

1. Disinfected secondary effluent shall not exceed 23 MPN/100 mL total coliforms for a 30-day median.

2. Disinfected secondary effluent shall not exceed 500 MPN/100 mL total coliforms for a 24-hour maximum.

Other NPDES requirements are summarized in Table 1 below.

TABLE 1

NPDES REQUIREMENTS
MANTECA WASTEWATER QUALITY CONTROL FACILITY

Constituent	Units	Effluent Limitations for Discharge to the San Joaquin River			
		30-day Avg.	7-day Avg.	30-day Median	Daily Max.
BOD_5	mg/L	20	30	--	50
Settleable Solids	mg/L	0.1	--	--	0.2
Total Suspended Solids	mg/L	20	30	--	50
Oil and Grease	mg/L	10	--	--	15
Chlorine Residual	mg/L	--	--	--	0.1
Acute Toxicity	% survivability	70[a]	90[b]		

[a] Minimum survival rate of aquatic organisms in 96 hour bioassay of undiluted waste for any one bioassay.
[b] Median survival rate of aquatic organisms in 96 hour bioassay of undiluted waste for any three or more consecutive bioassays.

HISTORICAL DISINFECTION PRACTICES

Secondary effluent from the Manteca wastewater facility is disinfected and dechlorinated prior to discharge to the San Joaquin River. To produce sufficient kill of pathogens, contact time is provided in converted secondary sedimentation basins. Historically,

wastewater disinfection has proven difficult however, because of short-circuiting in the basin, poor hydraulic design, and, a partially-nitrified effluent. The baffled "chlorine contact tanks" have an operational volume of approximately 310,000 gal which provides a theoretical detention time of 32 minutes at the current Phase II peak wet weather flow (13.45 mgd). The length to width ratio of the tanks is 60:1. A minimum contact time of 30 minutes at peak flow is required typically to satisfy a total coliform limit of 23 MPN/ 100 mL. Therefore, upon reaching the Phase II flow limits, the chlorine contact tanks will be at capacity. Treatment of Phase III peak wet weather flows (19.15 mgd) will require the construction of additional contact tank volume or an alternate disinfection system.

PROPOSED FUTURE DISINFECTION PROCESS

As noted earlier, wastewater discharged to the San Joaquin River is disinfected using chlorine gas and dechlorinated with sulfur dioxide to eliminate any chlorine residual. To satisfy effluent coliform limitations, a chlorine dosage of 17 mg/L is employed typically. Chlorine and sulfur dioxide gas storage and metering facilities include ton cylinders, evaporators, chlorinators, sulfonators, and injectors. Disinfection equipment has sufficient capacity to meet Phase II peak wet weather flow requirements but must be expanded to process the projected Phase III parameters. Rather than the continued use of gaseous chemicals for disinfection, however, conversion to a liquid alternative was considered for risk management purposes as a second alternative. Sodium hypochlorite ($NaOCl$) and sodium bisulfite ($NaHSO_3$) would be utilized in lieu of gaseous chlorine (Cl_2) and sulfur dioxide (SO_2). Although capital costs for the liquid alternative are lower than the conventional gas systems, overall life cycle costs for the $NaOCl$-$NaHSO_3$ option are significantly higher than the Cl_2-SO_2 arrangement.

A third alternative considered for wastewater disinfection was UV light. Based on previous operating experience with unfiltered secondary effluent, low pressure-high intensity UV systems were investigated as a disinfection option. Under this scenario, the existing chlorine contact tank would be retrofitted with UV lamps. An assessment of the three alternative disinfection processes is as follows.

Economic Comparison of Disinfection Alternatives

An economic comparison of disinfection alternatives (new chlorine contact tank-gaseous chemicals, new chlorine contact tank-liquid chemicals, retrofit existing contact tank with UV lamps) was undertaken to identify a potential future disinfection process. The probable capital and operating costs for the three disinfection alternatives evaluated are summarized in Table 2. It can be seen that the UV system has the highest cost due to its high capital and relatively high operating costs. The existing chlorination system is the least expensive, primarily due to the low cost of the disinfecting and dechlorinating agents.

TABLE 2

ECONOMIC COMPARISON OF DISINFECTION SYSTEM ALTERNATIVES FOR THE MANTECA WASTEWATER QUALITY CONTROL FACILITY

	Units	Cl_2 - SO_2	NaOCl - $NaHSO_3$	UV[a]
Capital Costs	$	1,500,000	1,250,000	2,400,000
Annualized Capital Costs[b]	$/yr	153,000	127,000	245,000
Operations and Maintenance Costs	$/yr	85,000	230,000	170,000
Total Annual Costs	$/yr	238,000	357,000	415,000

[a] Low Pressure-High Intensity UV System.
[b] Capital costs are amortized based on an interest rate of 8 percent and a design life of 20 years.

Evaluation of Disinfection Alternatives

A complete evaluation of the disinfection alternatives according to five criteria is summarized in Table 3. It can be seen that the UV disinfection system, despite being the most costly system, received the highest overall ranking. The UV system received significantly higher scores than the two chlorination alternatives considering environmental impacts and site requirements criteria. With respect to environmental impacts, it has already been noted that chlorination systems present a serious public health risk because of the potential for leaks of chlorine or sulfur dioxide gas during transportation, storage, and use. Additionally, chlorination systems can result in the production of trihalomethanes (THM), a family of carcinogenic organic compounds, from the mixture of free chlorine and organic materials. Moreover, nitrogen interaction results in decreased chlorine disinfection effectiveness. UV systems do not have any of the above environmental hazards.

With respect to the site requirements criterion, the UV alternative scored higher than the chlorination alternatives because of its ability to fit within the existing chlorine contact structure. Conversely, both chlorination alternatives required the construction of new concrete structures for chemical handling and chlorine contact.

In terms of performance, all three systems were given relatively equal scores, although, the UV system was discounted somewhat due to the lack of similar installation within the United States. Despite WQCF staff experience with chlorination, no preference was given in scores for compatibility criteria because of the staff's clear disfavor of the chlorination process. In view of the results of the alternatives comparison, retrofit of the existing chlorine contact tank with a UV system was recommended for further assessment as a disinfection process at the Manteca WQCF for the Phase III Expansion Project.

TABLE 3

EVALUATION OF EFFLUENT DISINFECTION ALTERNATIVES

Criteria	Weighting Factor (WF)	Cl_2 - SO_2		NaOCl - $NaHSO_3$		LP-HI UV	
		Score	WF x Score	Score	WF x Score	Score	WF x Score
Costs	3	4	12	3	9	2	6
Performance	3	3	9	3	9	3	9
Compatibility	2	4	8	3	6	3	6
Site Requirements	2	1	2	1	2	5	10
Environmental Impacts	1	1	1	3	3	5	5
Total			32		29		36

SELECTION OF UV DISINFECTION EQUIPMENT

Following selection of the UV alternative, further investigations of specific equipment suppliers were undertaken. A prequalification document was developed and responses were solicited from UV system manufacturers. Performance requirements for the UV disinfection equipment were established as follows for the Phase III Expansion Project:

1. Unfiltered secondary effluent flow:

   a. Average daily wastewater flow = 9.87 mgd
   b. Peak wet weather flow = 19.15 mgd

2. Disinfected secondary effluent quality shall not exceed 23 MPN/100 mL total coliforms for a 30-day medium and 500 MPN/100 mL total coliforms for a 24 hour maximum based on requirements (1a) and (1b) above and each of the below listed secondary effluent characteristics:

   a. Transmittance equal to 45%.
   b. Suspended solids equal to 20 mg/L.

The following information was then requested from potential suppliers:

1. Performance data for a minimum of five municipal wastewater treatment plants where UV disinfection equipment is utilized for the disinfection of <u>unfiltered</u> secondary effluent.

2. Catalogue information, equipment data, and published performance claims including but not limited to:

   a. Lamp manufacturer
   b. Lamp manufacturer's warranty
   c. Lamp output at 253.7 nm
   d. Lamp output at end of design life
   e. Procedure for pre-testing of the ballast and controls
   f. Procedure for burn-in of the lamps to be supplied
   g. Dosage calculation method

3. Complete layout drawings for concrete tankage depicting all equipment components, elevations, structural elements and electrical conduit required to satisfy the desired performance characteristics within one-half of the existing chlorine contact tank.

4. List of components, their sizes and materials of construction including, but not limited to:

   a. Automatic, in-channel wiping system

b. Low pressure lamp (mercury form, cleanup procedures if broken, lamp disposal requirements)
c. UV intensity meter
d. Ballast
e. Control panel

5. Electrical and control schematics;

6. List of recommended spare parts, number of recommended spare lamps, and nearest spare parts inventory location;

7. Description of quality control procedures including reference to ISO-9000 if appropriate.

8. Operation and maintenance manual.

9. Financial statement for the three most recently completed fiscal years which would demonstrate the manufacturer's financial condition.

10. Specific references that demonstrate the manufacturer's ability to provide comprehensive and timely repair, startup, and training services.

The City received submittals from three suppliers subsequently:

Inflico Degremont, Inc.
2924 Emerywood Parkway
Post Office Box 71390
Richmond, VA 23255-1390

PCI-Wedeco Ultraviolet Systems
One Fairfield Crescent
West Caldwell, NJ 07006

Trojan Technologies, Inc.
UV Disinfection Systems
3020 Gore Road
London, Ontario, Canada N5V 4T7

As specified in the equipment supplier qualification document, Inflico Degremont, Inc., and PCI-Wedeco Ultraviolet Systems proposed low pressure UV systems to meet the project design requirements. Trojan Technologies, Inc. did not submit a low pressure system but proposed a medium pressure alternative. The submittals from the three suppliers were evaluated subsequently and compared using the criteria described in the equipment supplier document. A tabular summary of the comparison is included as Table 4. Also, reference sites for Inflico Degremont, Inc., and PCI-Wedeco Ultraviolet System were contacted to verify equipment performance and water quality parameters.

Because the Trojan Technologies, inc., submittal did not propose on a low pressure system and their reference documents were incomplete, no follow-up site contacts were initiated.

The site survey consisted of telephone contacts with treatment plant operators listed by the respective equipment supplies. Design and operational parameters were confirmed and equipment performance was verified. Particular attention was given to sites with lower quality secondary effluent (i.e., low transmittance) similar to the Manteca WQCF. PCI-Wedeco equipment was present in a number of these installations as noted in Table 5. Further investigations identified additional low pressure – high intensity UV installations in the United States (see Table 6).

Based on the information presented in the qualification documents and the results of the subsequent site survey, PCI-Wedeco Ultraviolet Systems was recommended as the sole supplier qualified to provide disinfection equipment for the Phase III Expansion Project. This finding reflected the following:

1. PCI-Wedeco was the only supplier with extensive operational experience with poor quality (less than 50% transmittance), unfiltered secondary effluent. References verified the successful performance and quality of materials of the PCI-Wedeco low pressure-high intensity systems.

2. Lamp cleaning for the Infilco Degremont, Inc., UV system would require the removal of the lamps and immersion in an acid bath. The PCI-Wedeco system would accomplish lamp cleaning through the use of an in-channel automatic wiper system.

3. The number of lamps required for the PCI-Wedeco system was 20% of the number of lamps proposed by Infilco Degremont, Inc. It was questionable whether the lamp arrangement proposed by Infilco Degremont, Inc. (i.e., 6,000 lamps) would fit within the existing chlorine contact tank and still allow construction of the proposed effluent and plant water pump stations.

DETERMINATION OF REQUIRED DOSAGE

A preliminary study was conducted on January 12, 1998, by the Department of Civil and Environmental Engineering at the University of California at Davis to evaluate the feasibility of UV disinfection for secondary effluent at the City of Manteca WQCF. The purpose of the sampling was to assess the potential to meet a regulatory standard of 23 total coliform per 100 mL as measured by the multiple tube fermentation test. The response of total coliform bacteria was determined for three applied doses of UV light: 50, 101, and 153 mW-s/cm^2. The test results are provided in Table 7.

TABLE 4

COMPARISON OF ULTRAVIOLET LIGHT SYSTEM MANUFACTURERS FOR THE MANTECA WQCF PHASE III EXPANSION PROJECT

Manufacturer	PCI-WEDECO	IDI	Trojan
Operational Facilities			
Data Sheets Submitted	yes	yes	no
Equipment Description			
Catalogue Information			
Warranty (after 100 hrs burn in)	12,000 hrs (70%)	10,000 hrs (65%)	5,000 hrs (60%)
Lamp Output at 253.7 nm	95 watts	26.7 watts	2,800 watts
Procedure for Pre-testing of the Ballast and Controls	√	not included	√
Procedure for Burn-in of the Lamps to be Supplied	√	not included	√
Dosage Calculation Method	√	√	√
Pressure	low	low	medium
Number Lamps	1,000	5,760	320
Dose Recommended	100,000 $\mu Ws/cm^2$	107,550 $\mu Ws/cm^2$	109,050 $\mu Ws/cm^2$
Power Consumption	311 kW	396 kW	not provided
Arc Length	56.3 inch	58 inch	10 inch
Cleaning System	arm	Steel tank for acid bath	wiper collar
Inclination	horizontal	vertical	horizontal
Level Controller	weir	SS flap gate	submerged reactor
Shop Drawings Included	yes	yes	partial (equipment only)
List of Components			
Automatic, In-channel Wiping System	yes	no	yes
Low Pressure Lamp	yes	yes	no
UV Intensity Meter	yes	yes	yes
Ballast	yes	yes	yes
Control Panel	yes	yes	yes
Electrical and Control Schematics	yes	yes	yes
List of Recommended Spare Parts	yes	yes	yes
Description of Quality Control Procedures	yes	yes	no
Operation and Maintenance Manual	yes	yes	yes
Financial Statement Submitted	complete	partial	complete
Support Services	Valencia, CA W. Caldell, NJ	"throughout the country"	not submitted
Reliability/Maintainability/Expandability	Submitted	submitted	not submitted
Evidence of Equipment Performance	5 plants – unfiltered transmittance ≤45%	5 plants – unfiltered transmittance ≥50%	installation list only

TABLE 5

SUMMARY OF OPERATIONAL CHARACTERISTICS FOR SELECTED PCI-WEDECO INSTALLATIONS IN THE UNITED KINGDOM[a]

							MPN	
WWTP	Treatment Process	Design Flow (MGD)	Current Flow (MGD)	No. of UV Banks	Unfiltered Transmittance (%)	SS (mg/l)	Influent	Effluent
South West Water Perranporth (SW England)	No secondary, only primary w/chem dosing	1.5	0.4	4 in 2 channels	10	100	5.3×10^6	33,647
South West Water Ilfracrombe (SW England)	BAFF	3.7	3.7	2	45	60	1.05×10^5	826
Southern Water Camber(South Coast England)	Activated Sludge	0.9	0.9	2	45	20	1×10^5	300
Welsh Water St. Asaph (North Wales)	Biofilter (Trickling Filater)	2.05	106	2	45	30	81,000	96
Welsh Water Tenby (South Wales)	Activated Sludge	5.7	5.2	3	45	30	9.7×10^5	108

[a] Treatment plants required to meet EU discharge requirement guidelines for natural bathing water.

TABLE 6

PCI-WEDECO LOW PRESSURE – HIGH INTENSITY UV INSTALLATIONS IN THE UNITED STATES

Facility	Flow Rate (MGD)
City of Baldwin Florida WWTP, Baldwin, FL	1.01
Forest County Potawatomi WWTP, Carter, WI	<1
Village of Egg Harbor, WWTP Egg Harbor, WI	<1
Laona WWTP, Forest County, WI	<1
Hochunk Nation WWTP, Baraboo, WI	1.2
Sacramento Regional WWTP, California	<1

TABLE 7

SUMMARY OF INITIAL COLLIMATED BEAM TEST – MANTECA WQCF SECONDARY EFFLUENT JANUARY 12, 1998

Applied UV dose, [a] mW-s/cm^2	Total coliform, MPN/100 mL	Confidence Intervals	
		Low 95%	High 95%
0	1,162,000	520,000	2,260,000
50	128	56	253
101	13	6	25
153	8	3	16

[a] The wastewater transmittance at 253 nm light wavelength was 50.7%.

The results indicated that UV disinfection is potentially a viable alternative disinfectant. A design dosage of 100 mW-s/cm^2 was selected tentatively based on the initial collimated beam test. However, the analysis was based on a single grab sample and therefore process variability was not investigated.

A series of additional collimated beam tests were performed to confirm the required UV dosage. The results of the supplemented collimated beam tests are included as Table 8. It was not conclusive from this testing that a dosage of 100 mW-s/cm^2 would achieve the required coliform kill (23 MPN/100 mL total coliform), therefore, pilot testing was proposed. Considering the results of the prequalification process, a pilot study utilizing PCI-Wedeco low pressure-high intensity was undertaken.

TABLE 8

SUMMARY OF SUPPLEMENTAL COLLIMATED BEAM TESTS
MANTECA WQCF SECONDARY EFFLUENT

Date	Applied UV Dose mW-s/cm^2	Total Coliform MPN/100 mL	Confidence Intervals Low 95%	Confidence Intervals High 95%
May 18, 1998[a]	0	168,500	80,000	318,000
	49.2	42.7	22.9	72.5
	98.8	19.5	8.6	38.0
	147.4	9.3	3.3	20.2
May 27, 1998[b]	0	332,900	167,700	628,600
	50.2	116.9	52.0	225.9
	100.5	73.0	30.5	150.4
	150.4	35.8	16.4	69.5
June 9, 1998	0	251,000	123,400	480,000
	50.5	150.5	69.3	291.0
	99.9	170.5	77.0	341.9
	151.0	13.9	4.7	32.2

[a] Transmittance of 53.9% at 254 nm light wavelength.
[b] Transmittance of 49.7% of 254 nm light wavelength.

PILOT STUDY

Considering the required effluent quality, flow parameters, and anticipated transmittance, a pilot study was proposed for the selected UV disinfection equipment at the Manteca WQCF. Pilot study details are provided below.

Objectives

The purpose of the pilot study was to evaluate the effectiveness of the high intensity UV lamp technology manufactured by PCI-Wedeco on unfiltered secondary effluent. The study would be useful in confirming the final design of the UV disinfection system and determining the UV dose required to disinfect the unfiltered secondary effluent. Because of 24-hour variability in the quality of treated waste, the pilot study would also reveal fluctuations in the required dosage. More accurate design dosages could lead to a possible savings in capital cost due to reduced intensity and therefore power cost savings. An additional advantage to performing the pilot test would be the ability to observe the foul rate on the lamps. The effectiveness of this manufacturer's wiper system could then be witnessed firsthand.

Description of Pilot Equipment

A PCI-WEDECO TAK 55 Series UV disinfection system (TAK 2-1/143 x 3 cw), containing a total of twelve (12) Spektrotherm low pressure-high intensity mercury

amalgam lamps was used to conduct the pilot study. The lamps were arranged in three (3) uniform banks in series containing four (4) lamps each. A fixed overflow weir with the unit served to control the water level over the top lamps. Included with the pilot system was an electrical control panel and a compressor to operate the wiper system. PCI-WEDECO also provided a HIPPO ™ continuous UV transmittance monitor mounted separately from the pilot unit. Both the intensity sensor and the transmittance monitors were furnished with local digital readouts.

Installation of Pilot Equipment

The unit was shipped to the site and installed by the plant staff. The City provided the following:

1. A level surface for placement of the TAK pilot unit
2. A source of unchlorinated secondary effluent
3. A pump (approximately 5 hp) to provide a variable flow (range 100-250 gpm)
4. A 4 inch flow meter (totalizer) for installation on the upstream flow
5. 4 inch and 6 inch piping with fittings to connect from the source of secondary effluent to a 6 inch inlet on the pilot system
6. 6 inch piping for connection to outlet flanges on the pilot unit
7. Discharge point for effluent
8. Power supply 230 volt, single phase, 60 hertz, 10 amp service

After the unit arrived, and all parts required to be supplied by the City were assembled, a manufacturer's representative visited the site. The representative completed the installation of the unit and provided startup services and training.

Testing Procedures

The pilot unit was operated 24 hours per day, seven days per week for a three week period. Grab samples were taken each shift while the unit was in operation. Plant staff used the procedure described below.

1. Set the flow to the pilot unit at 150 gpm
2. Record the time and date, intensity and UV transmittance
3. Grab a sample of UV disinfected effluent
4. Increase the unit influent flow rate to 200 gpm
5. Record the time and date, intensity and UV transmittance
6. Grab a sample of UV disinfected effluent
7. Repeat the procedure of recording information and grabbing samples at an increased flow rate of 250 gpm

The specific sampling protocol included sampling three times a day at 4:00 a.m., 11:00 a.m., and 3:00 p.m. for influent suspended solids, % transmittance, and total and fecal coliforms. Total and fecal coliforms analyses were also performed on the disinfected effluent during the same corresponding influent sampling times.

Summary of Pilot Study Results

The pilot UV disinfection system was operated by the plant staff from April 16 – May 7, 1999. A summary of the UV disinfection equipment performance is provided in Table 9. Influent quality, UV dose, and effluent coliform concentration are included in the referenced table. A discussion of the results is as follows.

Hydraulics: The TAK system used for the pilot study included a fixed, standpipe weir designed to handle a maximum effective disinfection flow of 220 gpm. The disadvantage of this type of weir design is that it can not be adjusted with any varying water flow. Therefore, throughput exceeding the design parameters would result in a water layer too high above the top lamps. This would result in a potential for short-circuiting.

As the pilot testing progressed, it became apparent that at flow rates 150 gpm and greater the water level height above the top lamps exceeded 20 mm, the required design specification to insure optimal disinfection. This was due to the fixed weir setting height being designed incorrectly by the supplier. Consequently, performance at the higher flow rates may have been compromised by poor hydraulics.

Percent Transmittance: UV transmittance readings from the HIPPO unit were logged daily. Transmittance readings were fairly consistent in the range between 45-55% during the study period. There was some fluctuation with data points as low as 40% and some as high as 60%. However, in general, wastewater transmittance fell within the anticipated design range and reflected long-term operating conditions.

Intensity: There was variation in the intensity meter readings from bank-to-bank. This was most likely due to: 1) the meters required calibration, or, 2) the brushing mechanisms on the intensity monitors were not adjusted properly, and therefore, not operating efficiently. For small-scale TAK pilot systems the intensity monitors are used more for convenience than control. The intensity readings on the panel were relative and did not reflect the actual intensity of the lamps. The intensity used for calculating the dose in the pilot study was based on the point source summation method according to the EPA manual, and not the intensity monitor reading. The intensity monitors in full-scale TAK systems are designed and calibrated for control. The units monitor water quality, lamp fouling, and aging. The intensity readings in full-scale systems are used by the PLC for actual dose calculations.

UV Dose: The dose during the pilot study varied from 50 to 160 mW-s/cm^2. This variation was due to the changing % transmittance, as well as the changing retention time or flow. Dose is defined as the product of calculated average intensity and retention time. Average intensity is calculated using the EPA point source summation method, and retention time is the irradiation volume of the chamber divided by the flow rate. Because the volume is constant due to the fixed physical dimensions of the channel, the retention time will be directly proportional to the flow rate.

TABLE 9

SUMMARY OF UV PILOT DISINFECTION SYSTEM PERFORMANCE
APRIL 18 – MAY 3, 1999

Date	Time	Flow = 150 gpm				Flow = 200 gpm				Flow = 250 gpm			
		TSS, mg/L	Transmittance %	Dose, mWs/cm^2	Coliform, MPN/100 mL	TSS, mg/L	Transmittance %	Dose, mWs/cm^2	Coliform, MPN/100 mL	TSS, mg/L	Transmittance %	Dose, mWs/cm^2	Coliform, MPN/100 mL
4/18/99	4:00 am	17	58	165	4	17	58	124	130	17	58	99	3,000
	11:00 am	8	51.5	130	23	8	51.5	97	70	8	51.5	78	70
	3:00 pm	8	49	130	4	8	49	97	24	8	49	78	80
4/19/99	4:00 am	19	59	165	13	19	59	124	23	19	59	99	17
	11:00 am	6	56	165	13	6	56	110	50	6	56	88	50
	3:00 pm	8	49	130	2	8	49	97	13	8	49	78	22
4/20/99	4:00 am	11	53	130	23	11	53	86	70	11	53	69	500
	11:00 am	6	44	115	13	6	44	86	23	6	44	69	130
	3:00 pm	6	45	115	15	6	45	86	30	6	45	48	170
4/21/99	4:00 am	14	52	130	80	14	43.5	86	280	14	31.5	48	1,600
	11:00 am	10	47.5	115	30	10	47.5	86	50	10	47.5	69	80
	3:00 pm	9	45.5	115	17	9	45.5	86	30	9	45.5	69	280
4/22/99	4:00 am	12	49	130	50	12	40.5	77	240	12	31.5	48	900
	11:00 am	9	46.5	115	4	9	47.8	97	50	9	47	69	170
	3:00 pm	11	45.5	115	13	11	45.5	86	17	11	45	69	140
4/23/99	4:00 am		51	130	80		50.5	97	11		47	69	300
	11:00 am	27	44	115	4	27	44.5	86	2	27	43	69	280
	3:00 pm	8	43.5	115	17	8	44	86	13	8	43.5	69	130
4/24/99													
	11:00 am	7	59	165	8	7	59	124	23	7	59	99	36
	3:00 pm	11	47.5	130	50	11	47.5	97	30	11	47.5	78	170
4/25/99	5:00 am	14	55	146	4	14	55.5	110	17	14	55	88	33
	11:00 am	10	52.5	146	4	10	52.5	97	17	10	53.5		
	3:00 pm	9	47.5	30	30	9	47	97	50	9	47	78	900
4/26/99	5:00 am	14	60.5	165	2	14	60.5	124	23	14	60	99	8
	11:00 am	4	52.5	130	13	4	52	97	22	4	52.5	78	240
	3:00 pm	8	53	146	11	8	52.5	97	23	8	52	78	170

TABLE 9

SUMMARY OF UV PILOT DISINFECTION SYSTEM PERFORMANCE
APRIL 18 – MAY 3, 1999

Date	Time	Flow = 150 gpm				Flow = 200 gpm				Flow = 250 gpm			
		TSS, mg/L	Transmittance %	Dose, mWs/cm²	Coliform, MPN/100 mL	TSS, mg/L	Transmittance %	Dose, mWs/ cm²	Coliform, MPN/100 mL	TSS, mg/L	Transmittance %	Dose, mWs/cm²	Coliform, MPN/100 mL
4/27/99	5:00 am	11	62.5	163	4	11	62	124	20	11	61.5	99	17
	11:00 am	8	62.5	165	2	8	63	124	2	8	62.5	99	140
	3:00 pm	8	56.5	146	2	8	56	110	13	8	56	88	50
4/28/99	5:00 am	33	46	115	21	33	45.5	86	22	33	44.5	69	80
	11:00 am	8	48.5	130	11	8	48	97	90	8	48	78	500
	3:00 pm	12	45	115	2	12	45	86	1,600	12	44.5	69	80
4/29/99	5:00 am	11	45	115	<2	11	45	86	50	11	45	69	80
	11:00 am	7	41.5	102	30	7	41.5	77	300	7	41.5	61	900
	3:00 pm	7	43	130	13	7	43	86	300	7	42.5	69	1,600
4/30/99	5:00 am	14	49.5	130	26	14	49.5	97	75	14	49.5	78	300
	11:00 am	6	44	115	30	6	44	86	80	6	43.5	69	1,600
	3:00 pm	8	43.5	115	13	8	43.5	86	34	8	44.5	69	1,600
5/1/99													
	11:00 am	10	46	115	7	10	47.5	97	30	10	47.5	78	900
	3:00 pm	12	40	102	70	12	40.5	87	50	12	40		
5/2/99	5:00 am	13	48.5	130	4	13	48.5	97	17	13	48	78	70
	11:00 am	9	42.5	102	4	9	42	77	30	9	42	61	240
	3:00 pm	7	34.5	90	80	7	34	68	240	7	35	54	>1,600
5/3/99	5:00 am	15	50	130	11	15	49.5	97	8	15	50	78	130
	11:00 am	8	41	102	2	8	41.5	77	30	8	42.5	61	500
	3:00 pm	8	45		2	8	44.5	86	30	8	44.5	69	220

Performance: As might be expected, disinfection results were best at the lower flow rate, 150 gpm as summarized in Table 9. As flows increased, final coliform levels also increased, probably due to short-circuiting caused by poor hydraulics through the UV lamp banks. However, for UV doses of 100 mW-s/cm^2 or greater, the disinfected secondary effluent standard of 23 MPN/100mL total coliform was satisfied consistently.

Conclusions and Recommendations

Based on the results of the pilot study, the following conclusions and recommendations were offered:

1. The PCI-Wedeco TAK 55 Series UV disinfection system was effective in achieving significant reductions in effluent coliform levels on unfiltered secondary effluent. The automatic wiper system operated efficiently in reducing the fouling rate of the Spektrotherm low pressure-high intensity mercury amalgam lamps.

2. Disinfection criteria of not exceeding 23 MPN/100 mL total coliforms (median) and 500 MPN/100 mL total coliform for a 24-hour period can be achieved with a design dose of 100 mW-s/cm^2.

3. The Spektrotherm low pressure-high intensity lamps should be incorporated into full-scale disinfection system design for the Phase III Expansion project.

UV SYSTEM DESIGN FOR THE MANTECA WQCF

Based on the pilot study results, a preliminary design of the UV disinfection facility was prepared. Design criteria are presented in Table 10. Capital costs and projected operation/maintenance costs are summarized in Tables 11 and 12, respectively. Installation of the proposed UV system is illustrated in Figure 2 and 3.

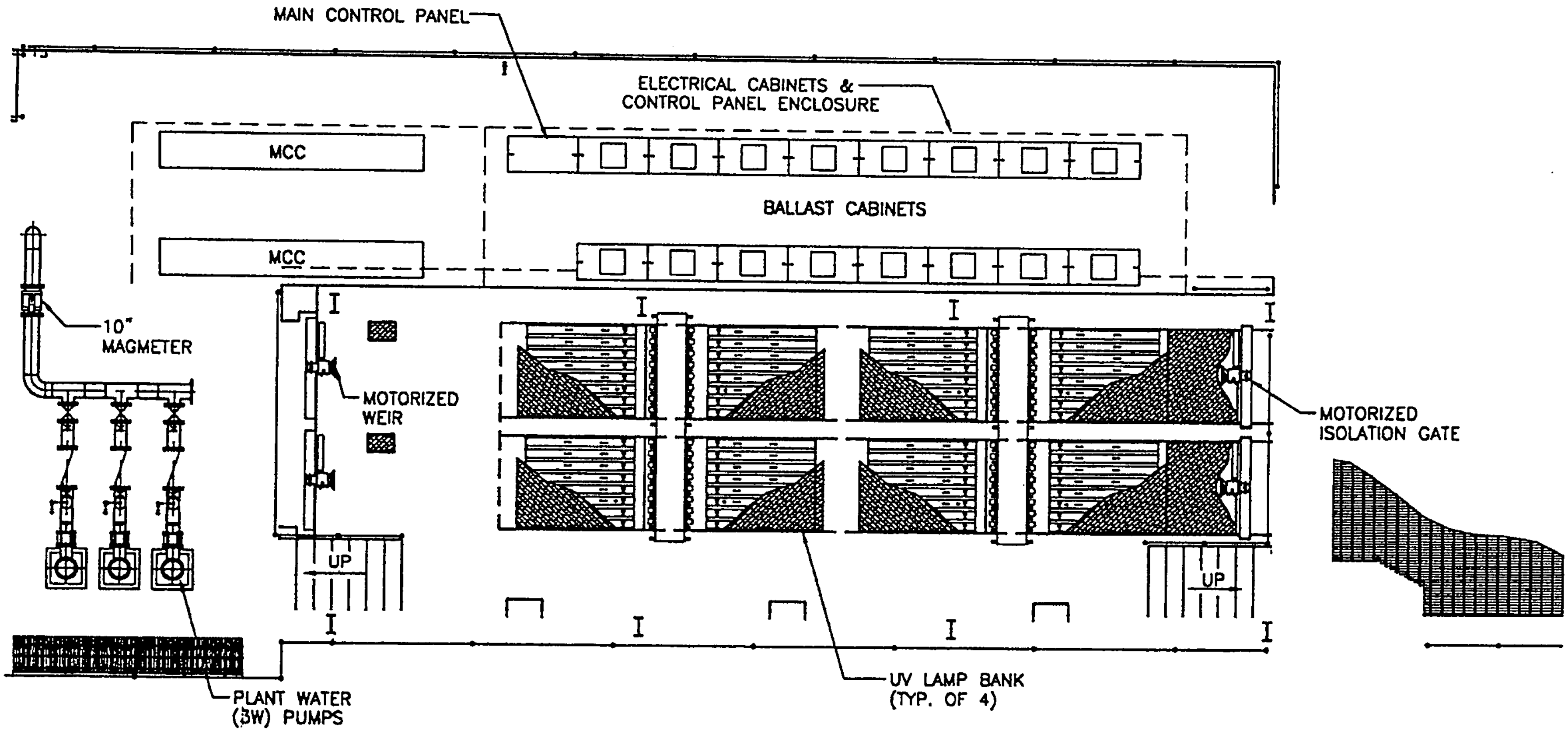

FIGURE 2

PLAN VIEW
OF ULTRAVIOLET
LIGHT DISINFECTION
SYSTEM

NOLTE
BEYOND ENGINEERING

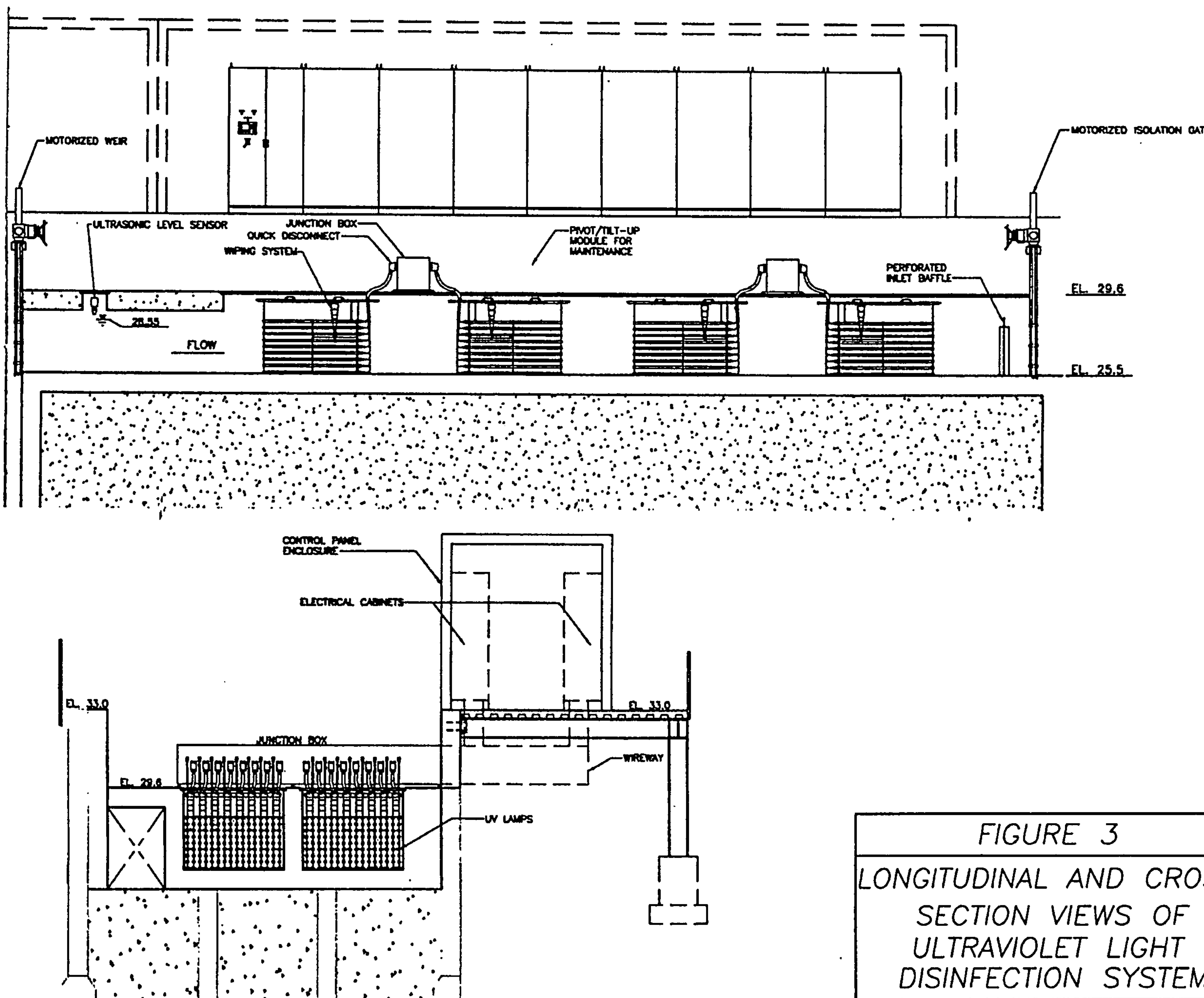

FIGURE 3

LONGITUDINAL AND CROSS SECTION VIEWS OF ULTRAVIOLET LIGHT DISINFECTION SYSTEM

NOLTE
BEYOND ENGINEERING

TABLE 10

SUMMARY OF DESIGN CRITERIA FOR UV DISINFECTION SYSTEM
MANTECA WQCF PHASE III EXPANSION PROJECT

Parameter	Units	Value
Average dry weather flow	mgd	9.87
Peak wet weather flow	mgd	19.15
Disinfection channels	ea	2
UV banks, per channel	ea	4
UV lamps per bank	ea	112
UV lamps, total	ea	896
Number of banks operational at ADWF	ea	4
Number of banks operational at PWWF	ea	8
Dose	$mW\text{-}s/cm^2$	100
Power consumption, peak flow	W	310

TABLE 11

SUMMARY OF PROBABLE CONSTRUCTION COSTS
UV DISINFECTION EQUIPMENT
MANTECA WQCF PHASE III EXPANSION PROJECT

Description	Probable Cost ($)
Structural Demolition within Existing Tank	55,000
Concrete	164,000
Structural Steel	80,000
Miscellaneous Metals	7,000
Slide Gates	30,000
Hoist and Trolley	12,000
UV Equipment	1,600,000
Electrical Work	400,000
Total	2,400,000

TABLE 12

SUMMARY OF PROBABLE OPERATION AND MAINTENANCE COSTS
UV DISINFECTION EQUIPMENT
MANTECA WQCF PHASE III EXPANSION PROJECT

Description	Annual Cost ($)/yr
Personnel	30,000
Power	120,000
Lamp Replacement	20,000
Total	170,000

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